(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 886 128 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
29.09.2021 Bulletin 2021/39

(51) Int Cl.:
H01H 1/00 *(2006.01)* ***H01H 11/00*** *(2006.01)*
H01H 71/04 *(2006.01)*

(21) Application number: **20165095.9**

(22) Date of filing: **24.03.2020**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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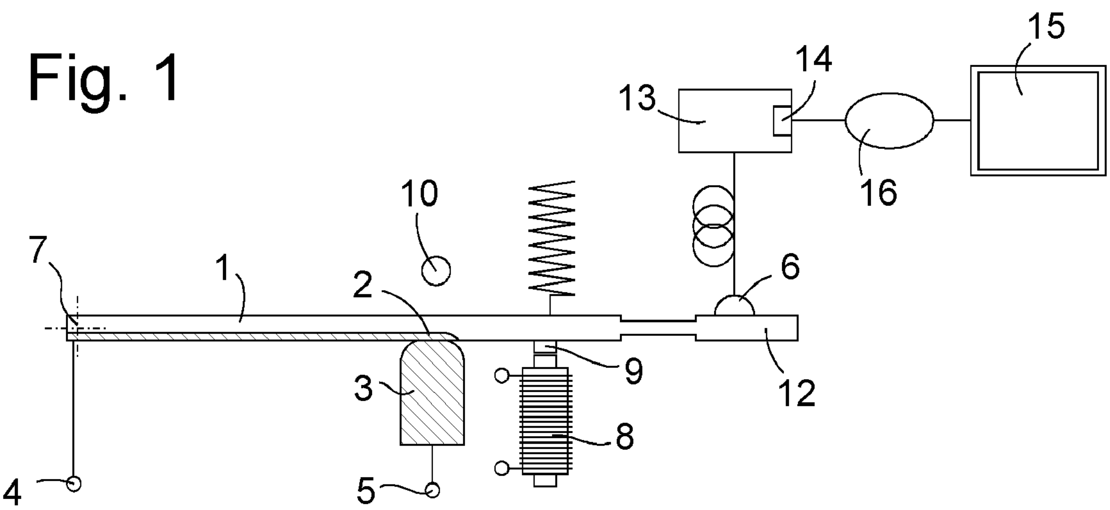
(54) **ELECTRICAL SWITCHING DEVICE**

(57) An electrical switching device comprises a stationary member (3), a mobile member (1) which is displaceable between a closed position in which a contact pad (2) of the mobile member (1) is in electrically conductive contact with the stationary member (3), and an open position in which the electrically conductive contact does not exist, and an actuator (8, 18) for displacing the mobile member (1) from at least a first one of the closed and open positions to the second one. An acceleration sensor (6) is coupled to the mobile member (1) so as to sense an acceleration caused by the actuator (8, 18) displacing the mobile member (1).

Fig. 1



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Description

[0001] The present invention relates to a device for switching electrical currents and/or voltages, typically for power switching, such as a relay or a circuit breaker.

[0002] These devices typically comprise a stationary member, a mobile member that is displaceable between a closed position in which a contact pad of the mobile member is in electrically conductive contact with the stationary member, and an open position in which there is no electrically conductive contact, and an actuator for displacing the mobile member. When in such a device the mobile member is moved into or out of the closed position while a voltage is applied to the mobile and stationary members, an arc may form when the distance between the members is small enough but not zero, deteriorating the quality of the contacting surfaces of the mobile and stationary members. This may cause the surfaces to adhere to each other. Initially, weak adhesion may merely delay the switching operation, but if finally adhesion becomes too strong for the actuator to overcome, switching is prevented. Similarly, mechanical wear of the mobile member and its bearings may first merely delay the switching operation and finally prevent it altogether. Mechanical breakage might even cause the switching movement to become faster than normal, if the inertia of moving components is reduced.

[0003] EP 2 290 666 A1 discloses a switching device in which an end position switch or a light barrier is used for controlling whether an end position is properly reached. If it isn't reached, the device is defective and must be replaced, but the defect cannot be predicted before it actually occurs.

[0004] WO 2018/108833 A1 discloses an electrical switching device in which life expectancy of a switching device is predicted based on its chattering behaviour, derived from current flowing through a Reed contact or through the solenoid driving the switching movement. This is a rather indirect way of judging life expectancy, since arc formation is not necessarily accompanied by chattering, but if arcs are formed, chattering will accelerate wear of contact surfaces. Therefore, if it is attempted to minimize downtime of a system by replacing switching devices thereof when these show suspicious chattering, there is a considerable probability that a switching device is replaced prematurely. Although such a replacement can be planned, and downtime for replacement can be kept short, it still causes an interruption of operation of the system in which the switching device is used, and potentially unnecessary cost. In order to minimize the number and duration of such interruptions, there is a need for a switching device where the likeliness of impending failure can be predicted reliably regardless of its cause.

[0005] The present invention achieves or at least comes closer to this goal by means of an electrical switching device comprising a stationary member, a mobile member which is displaceable between a closed position in which a contact pad of the mobile member is in electrically conductive contact with the stationary member, and an open position in which the electrically conductive contact does not exist, and an actuator for displacing the mobile member from at least a first one of the closed and open positions to the second one, characterized by an acceleration sensor which is coupled to the mobile member so as to sense an acceleration caused by the actuator displacing the mobile member. The acceleration sensor is capable of detecting any irregularity of movement of the displaceable member, regardless of its cause.

[0006] The actuator can be of any type, but typically comprises a solenoid adapted to interact magnetically with the mobile member. In an automatic fuse, most of the energy driving a displacement of the mobile member may be provided by a spring, the magnetic interaction of the solenoid merely serving to unlock the mobile member so as to enable its displacement by the spring.

[0007] The acceleration sensor can be a micromechanical sensor. Such sensors are rugged and suitable for use in any orientation relative to the gravity vector. They are in widespread use e.g. for controlling airbags in motor vehicles and are therefore available at low cost.

[0008] In order to maximize sensitivity, the acceleration sensor can be coupled to the mobile member so that the distance between a first position of the sensor associated to the open position and a second position of the sensor associated to the closed position is longer than the path of the contact pad between the open and close positions. Specifically, the sensor and the contact pad can be rotatable by a same axis, the radius of the acceleration sensor being longer than that of the contact pad.

[0009] The acceleration sensor can be fixedly integrated into the mobile member, in order to follow its displacement as closely as possible.

[0010] Alternatively, the acceleration sensor might be resiliently coupled to the mobile member. This can be useful in particular if the duration of the displacement of the displaceable member is known and constant; in that case the resonance period of the sensor mount can be tuned to the duration of the displacement so that any variation of that duration has a noticeable effect on the vibration of the sensor caused by the displacement.

[0011] The bandwidth of the acceleration sensor should be high enough to obtain at least one acceleration measurement, i.e. higher than the inverse of the duration of a displacement of the mobile member between the open and closed positions. Preferably, it should be high enough to allow taking a plurality of acceleration measurements in the course of a displacement of the mobile member.

[0012] The switching device may be associated to a processing unit which is adapted, e.g. programmed, to derive a judgment on the integrity of the switching device from current acceleration data obtained in relation to a current displacement of the mobile member between the first and second positions driven by the actuator.

[0013] The switching device and the processing unit can be associated in the form of an assembly for joint installation.

[0014] Alternatively, the processing unit can be remote from the switching device, communicating with the acceleration sensor via a digital network such as a LAN or the Internet.

[0015] The processing unit can be adapted to derive the judgment on the integrity of the switching device from a comparison of said current acceleration data with standard acceleration data.

[0016] Such standard acceleration data can be predetermined data, which may be provided by the manufacturer, for a specific type of switching device.

[0017] Preferably, the processing unit is adapted to derive the standard acceleration data (or to update earlier standard data such as those provided by the manufacturer as mentioned above) based on acceleration data obtained in relation to earlier displacements of said mobile member. In that way, not only individual characteristics of the switching device that is being monitored can be taken into account, but also the influence of the orientation in which it is installed, in particular an influence of gravity on the displacement of the mobile member.

[0018] The current acceleration data that are provided by the acceleration sensor in relation to a current switching movement should cover a time interval before and after an instant in which the mobile member reaches the second position. As is easily understood, data obtained before that instant are indicative of the condition of the mobile member in its first position, such as possible sticking, and of movement from the first position to the second, whereas data obtained after reaching the second position allow to draw conclusions on the condition of the mobile member in the second position.

[0019] The switching device may comprise a network interface for outputting data of the acceleration sensor obtained in relation to a displacement of the mobile member, or data derived from these, e.g. by a local processing unit.

[0020] Further features and advantages of the invention will become apparent from the subsequent description of embodiments thereof, referring to the appended drawings.

Fig. 1 is a schematic diagram of a relay according to the present invention;

Fig. 2 is a schematic diagram of a circuit breaker or an automatic fuse according to the present invention; and

Fig. 3 is an exemplary diagram of a switching movement.

[0021] Fig. 1 is a highly schematic representation of components of a relay. The relay has a mobile member 1, which is displaceable between an closed position in which a contact pad 2 of mobile member 1 is in electrically conductive contact with a stationary member 3, allowing a current to flow between terminals 4, 5, and an open position in which the mobile member 1 is physically separate from the stationary member 3, so that the electrical current between terminals 4, 5 is interrupted.

[0022] The mobile member 1 carries an acceleration sensor 6. The acceleration sensor 6 is electrically isolated from contact pad 2. The mobile member 1 can e.g. be an elongate metallic body locally covered by an insulator layer to which the acceleration sensor 6 is affixed.

[0023] The acceleration sensor 6 can comprise at least one micromechanical sensor, each e.g. etched from a silicon substrate, comprising an inertial body forming a first capacitor plate, elastically displaceable in the direction of displacement of the mobile member 1, e.g. by at least one resilient web connecting the inertial body to a frame, and a second capacitor plate spaced in the direction of displacement from the frame by an insulating layer and from the inertial body by a gap, so that the capacitance of a capacitor formed by said first and second plates varies depending on the distance between the capacitor plates, and acceleration of the mobile member 1 can be judged based on said capacitance, e.g. from the resonance frequency of a resonator circuit which includes the capacitor.

[0024] If desired, further micromechanical sensors can be provided whose inertial body is displaceable in another direction, typically perpendicular to the displacement direction of the mobile member 1.

[0025] In a miniaturized embodiment, it would be conceivable to form the complete mobile member 1 from a semiconductor substrate, doped in a first region to form the contact pad 2 and doped and etched in a second region to form the sensor or sensors 6.

[0026] Displacement of the mobile member 1 between open and closed positions is driven by a solenoid 8 interacting with a ferromagnetic body 9 attached to mobile member 1. In the embodiment shown, magnetic attraction between the solenoid 8 and the ferromagnetic body 9 holds the mobile member 1 in the closed position. A spring, not shown, may be provided for moving mobile member 1 into an open position, not shown, in which mobile member 1 is in contact with an abutment 10.

[0027] The movement of mobile member 1 can be a translation. In the present embodiment, it is a rotation by an axis 7 perpendicular to the plane of Fig. 1. The sensor 6 is located at a longer radius with respect to axis 7 than the contact pad 2, in order to be subject to a large and precisely detectable acceleration when moving between the open and closed positions.

[0028] In this embodiment, the radius of the sensor 6 with respect to axis 7 is also longer than that of abutment 10, and the sensor 6 is able to vibrate with respect to the mobile member 1, symbolized here by a sensor mount 12 connected to the mobile member 1 by a tapered portion 11. This flexibility enables the sensor 6 to overshoot when the movement of the mobile member 1 is stopped by the abutment 10, so that acceleration data obtained from the sensor 6 after the mobile member 1 making contact with the abutment 10 can be used for drawing conclusions on the state of the device. For example, a resonance frequency of the mobile member 1 may be adapted to an expected duration of the movement of mobile member 1 between open and closed positions, so that as long as the movement does take the expected time, the overshoot is maximized, whereas when wear causes the movement to become slower or faster, this can be detected due to the reduction in overshoot.

[0029] Acceleration data from sensor 6 are collected by a processing unit 13. The processing unit 13 can be a microcontroller or the like, accommodated in a same housing with the relay, or otherwise forming an assembly together with the relay.

[0030] The processing unit 13 may come with a predefined set of data stored in it with which to compare data provided by the acceleration sensor 6 whenever the mobile member 1 is displaced between open and closed positions. Preferably, such a set of data is obtained from measurements carried out on the first displacements carried out by the mobile member 1 when the switching device is still new and can be assumed to be in good order. By comparing data obtained in later displacements with these, wear of the switching device can be detected, as will be explained in more detail later. The result of such a detection, output by processing unit 13, can be a binary judgment indicating that the relay is either in working order or is due for replacement. It can also be a quantitative score representative of the overall quality and/or expected remaining service life of the relay.

[0031] The processing unit 13 includes a network interface 14 for communication with a remote unit 15 by a network 16 such as a LAN, a wireless network and/or the Internet. The remote unit 15 may collect information from a plurality of processing units 13. For instance, it can be run by an operator of an industrial plant to collect data from processing units of the entire plant or of subunits thereof, in order to keep maintenance staff informed of existing or imminent need to replace a relay or other device associated to one of these processing units. In particular if the network 16 is a WAN or the Internet, the remote unit might also be run by a manufacturer of the relay, in order to be able to predict the when and where of future demand for replacement.

[0032] Fig. 2 is a schematic diagram of an automatic fuse or a circuit breaker according to the present invention. The circuit breaker has many components in common with the relay of Fig. 1; these components are depicted identically in Figs. 1 and 2 and have identical reference numerals; their description will not be repeated. The main difference between the two devices is that while in the relay, the solenoid 8 must overcome the force of the spring acting on the mobile member 1 and is thus capable of controlling displacement from open to closed position and vice versa, the solenoid 8 of the circuit breaker is designed to withdraw a latch 17 which locks mobile member 1 in its closed position. When that happens, a spring 18 urges mobile member 1 into the open position, i.e. the acceleration measured by sensor 6 is due to the force of the spring 18. In order to bring the mobile member 1 back into the closed position, manual intervention is necessary.

[0033] Fig. 3 illustrates the movement of mobile member 1 when moving from closed to open position in the relay of Fig. 1 or the circuit breaker of Fig. 2. A curve x, representative of the position of the mobile member 1, starts from the closed position, the speed, represented by curve v, starts from zero. A curve a illustrates the acceleration; when the mobile member 1 is being displaced, acceleration sensor 6 provides samples of this curve a.

[0034] In a first phase (i), while the mobile member 1 moves towards the open position, the parabolic shape of curve x and the linear shape of curve v are representative of approximately constant negative acceleration a. The amount of this acceleration is governed by friction and by inertia of the mobile member and components coupled to it. When friction increases, the amount of acceleration decreases, so that a possible impending failure of the device may be predicted by processing unit 13 if this amount drops below a predetermined fraction of a normal acceleration measured for the same device when freshly installed. If, on the other hand, acceleration is higher than said normal acceleration, it must be expected that some mechanical connection within the device is broken, in which case the processing unit should output a signal calling for immediate replacement of the device.

[0035] Duration of said first phase (i) should be inversely proportional to the amount of acceleration; therefore, the processing unit 13 can make use of the number of samples obtained in the first phase (i) to check plausibility of the detected acceleration amount. If the proportionality is violated, the path of the mobile member 1 may be obstructed, or the sensor 6 itself might be defective; in either case replacement of the device should be called for.

[0036] When the mobile member reaches abutment 10, acceleration switches to a high positive value. The amount of the positive acceleration and the duration of the (second) phase (ii) in which it persists depend on elasticity of abutment 10 and of the sensor mount, due e.g. to tapered portion 11. If there is no rebound, sums of accelerations measured in the first and second phases (i), (ii) should sum up to approximately zero. In case of rebound, the sum will be positive, and a third phase (iii) with negative acceleration will follow. If it doesn't, again there is reason to suspect some malfunction that might make replacement necessary.

[0037] In a simple embodiment, requiring only a low temporal resolution of the acceleration sensor 6, it may be sufficient simply to monitor the duration of alternating phases of positive and negative acceleration after a displacement of the mobile member 1. When the normal duration of the displacement (i.e. phase (i)) is tuned to the resonance period of the sensor mount, any increase or decrease of this duration will cause the vibration of the sensor mount to be excited less efficiently than normal, so that the number of subsequent phases (ii), (iii), ...

showing accelerations in opposite directions strong enough to be detected will decrease. Here, simply the number of direction changes of the acceleration detected after a displacement of the mobile member 1 may be taken as an indicator of the status of the device, a replacement of the device becoming the more urgent, the smaller the number of detected direction changes is.

Reference numerals

[0038]

1	mobile member
2	contact pad
3	stationary member
4	terminal
5	terminal
6	acceleration sensor
7	axis
8	solenoid
9	ferromagnetic body
10	abutment
11	tapered portion
12	sensor mount
13	processing unit
14	network interface
15	remote unit
16	network
17	latch
18	spring

Claims

1. Electrical switching device comprising a stationary member (3), a mobile member (1) which is displaceable between a closed position in which a contact pad (2) of the mobile member (1) is in electrically conductive contact with the stationary member (3), and an open position in which the electrically conductive contact does not exist, and an actuator (8, 18) for displacing the mobile member (1) from at least a first one of the closed and open positions to the second one,
characterized by an acceleration sensor (6) which is coupled to the mobile member (1) so as to sense an acceleration caused by the actuator (8, 18) displacing the mobile member (1).

2. The electrical switching device of claim 1, wherein the actuator (8, 18) comprises a solenoid (8) adapted to interact magnetically with the mobile member (1).

3. The electrical switching device of claim 1 or 2, wherein the acceleration sensor (6) is a micromechanical sensor.

4. The electrical switching device of any of the preceding claims, wherein the acceleration sensor (6) is coupled to the mobile member (1) so that the distance between a first position of the sensor (6) associated to the open position and a second position of the sensor (6) associated to the closed position is longer than the path of the contact pad (2) between the open and close positions.

5. The electrical switching device of any of claims 1 to 4, wherein the acceleration sensor (6) is fixedly integrated into the mobile member (1).

6. The electrical switching device of any of claims 1 to 4, wherein the acceleration sensor (6) is resiliently coupled to the mobile member (1).

7. The electrical switching device of any of the preceding claims, wherein the bandwidth of the acceleration sensor (6) is higher than the inverse of the duration of a displacement of the mobile member between the open and closed positions driven by the actuator.

8. The electrical switching device of any of the preceding claims, **characterized in that** it is a relay, a circuit breaker or an automatic fuse.

9. An assembly comprising the electrical switching device of any of the preceding claims and a processing unit (13) for deriving a judgment on the integrity of the switching device from current acceleration data (a) obtained in relation to a current displacement of the mobile member (1) between the first and second positions driven by the actuator (8, 18).

10. The assembly of claim 9, wherein the processing unit (13) is adapted to derive the judgment from a comparison of said current acceleration data (a) with standard acceleration data.

11. The assembly of claim 10, wherein the processing unit (13) is adapted to derive the standard acceleration data from acceleration data obtained in relation to earlier displacements of said mobile member (1).

12. The assembly of claim 9, 10 or 11, wherein the current acceleration data (a) cover a time interval (i, ii, iii, ...) before and after an instant in which the mobile member (1) reaches the second position.

13. The assembly of any of the preceding claims, further comprising a network interface (14) for outputting data of the acceleration sensor (6) obtained in relation to a displacement of the mobile member, or a judgment derived from these.

Fig. 1

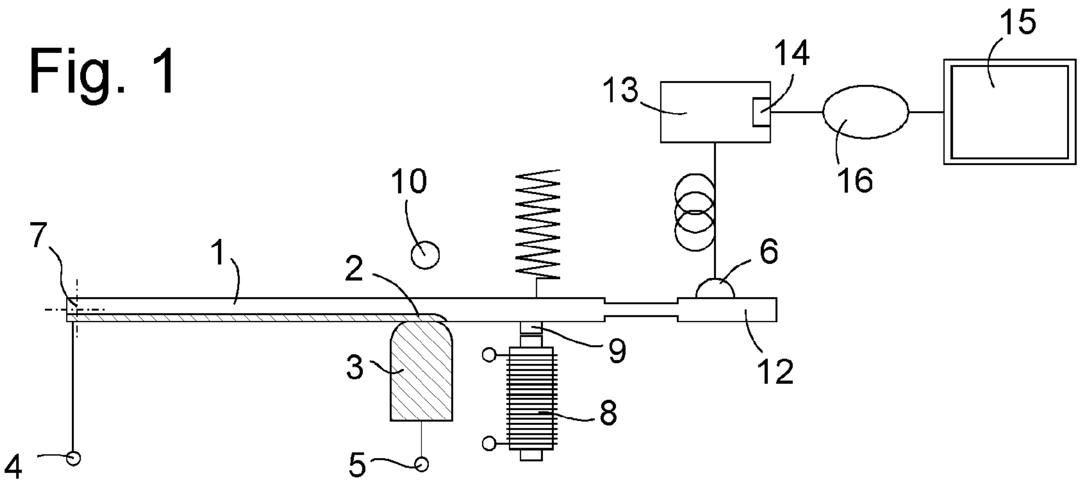


Fig. 2

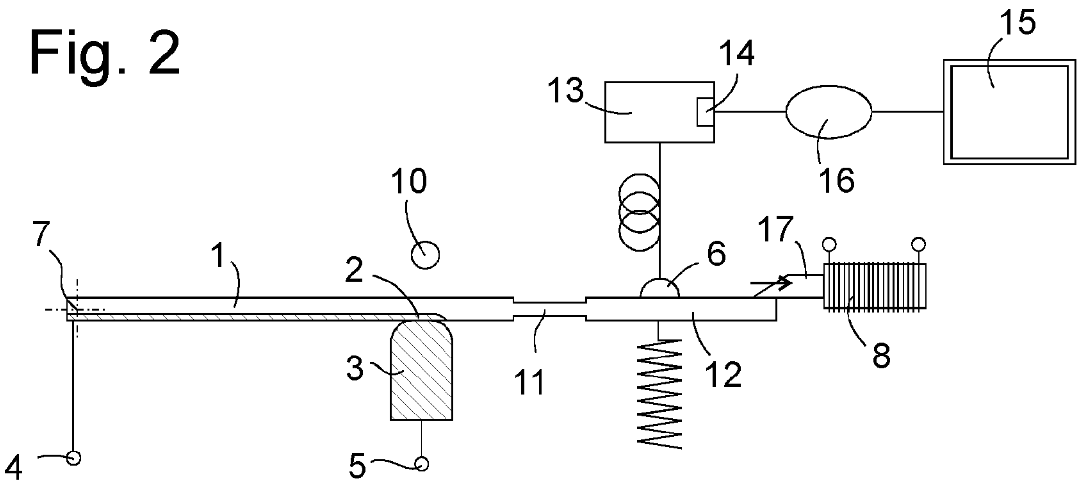
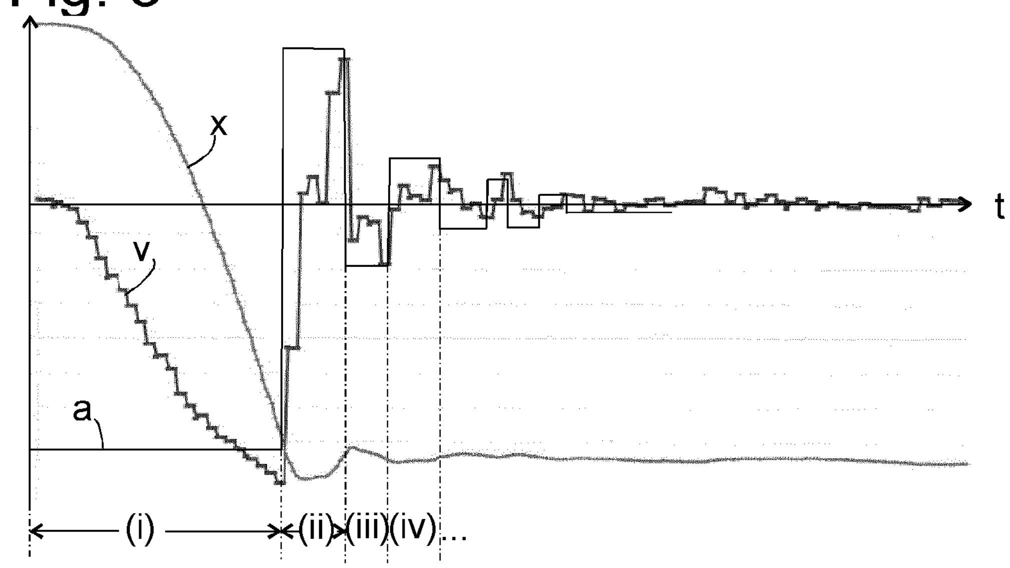


Fig. 3



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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 5095

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
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CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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